Light Energy Demonstration

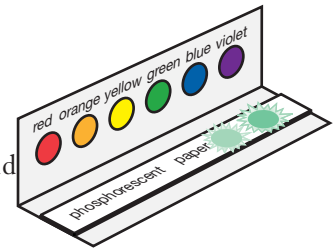
Introduction

Students often confuse the concepts of intensity of light and energy of light. This demonstration provides a clear way to demonstrate that the intensity, or brightness, of light is NOT the same as the amount of energy a particular color of light possesses.

Chemical Concepts

- Phosphorescence
- Transmittance/Absorbance

Materials



Energy in Photons Demonstrator Card—containing phosphorescent strip and light filters

Light source—classroom lights or overhead projector

Procedure

1. Open the Demonstrator Card and show the class the phosphorescent strip. Explain to them that the common term for phosphorescence is "glow-in-the-dark" and that this strip will glow in the dark.
2. Directly expose the entire phosphorescent strip to the classroom lights for about 15 seconds. Now turn off all the classroom lights and completely darken the room. The entire strip will glow brightly for several minutes and then begin to fade.
3. Show the six colored filters on the Demonstrator Card to the class. Hold the Demonstrator Card up to the light so that the color of light transmitted through each filter is clearly visible. Observe that the color of light transmitted through each filter is the same color as the filter.
4. Have the class predict what will happen if the Demonstrator Card is closed so that only "filtered" light is allowed to shine upon the phosphorescent strip.
5. Close the Demonstrator Card tightly making sure that no light can reach the phosphorescent strip from the sides. Paper clip the sides closed. Expose the closed Demonstrator Card to the classroom lights for at least 30 seconds.
6. Now turn off all the classroom lights and completely darken the room again. Open the Demonstrator Card and show the phosphorescent strip to the class. The strip will only glow under the blue and violet filters!
7. Compare the class' predictions with the actual results. Many students will be surprised that the "lighter" colors, like yellow and orange, did not let "enough light" through to cause the strip to glow.

Tips

- The spots under the blue and violet filters should always glow brightly, but sometimes a small glow can be seen under some of the other filters. This is partly due to stray light creeping in around the filters. Try to keep the Demonstrator Card as tightly closed as possible to prevent any extra light from getting to the phosphorescent strip. The slight glow can also be explained by noting that the filters are not "perfect" filters in removing lights of other wavelengths.
- To store the Demonstrator Card, insert a solid black strip into the Card so that it is covering the phosphorescent strip. Close the Demonstrator Card and store it in an envelope.

Discussion

The visible portion of the electromagnetic spectrum spans the wavelength region from about 400 to 700 nm. The human eye sees light of 400 nm as violet and 700 nm as red. Based on the quantum nature of light, the wavelength of light is inversely proportional to its energy (E) according to Planck's Law, $E = hc/\lambda$, where h is Planck's constant and c is the speed of light. Because it has a shorter wavelength than red light, violet light is higher in energy than red light. As the color of light changes, so does the amount of energy it possesses. White light, such as that from an incandescent or fluorescent light, contains all of the colors in the visible spectrum.

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A second characteristic of light, in addition to its energy, is its intensity. Intensity corresponds to the brightness of light. According to the theories of classical physics, energy should be proportional to intensity, so that the more intense a light source, the more energy it gives off. Under this assumption, very bright (yellow) light should cause the phosphorescent strip in the Demonstrator Card to glow. However, this is not observed! Instead, the phosphorescent strip glows only when blue or violet light is shined on it. This phenomenon can only be explained in terms of the quantum nature of light and Planck's Law.

The glowing of the phosporescent strip in the Demonstrator Card is due to two processes that occur in tandem. First, the phosphor must absorb light of the proper energy to excite an electron from its lowest energy ground state to a higher energy excited state. Once in the excited state, the electron has a natural tendency to want to return back to its more stable ground state. In doing so it releases energy in the form of light—this is the emission of photons that is observed as "glow-in-the-dark" phosphorescence. The phosphorescent material has a critical wavelength or energy of light. If a light is shined on the phosphorescent strip and it contains photons whose energy is greater than the energy needed to cause the strip to glow, it will glow. If the intensity of this source is increased, the strip will glow more brightly. If, however, a light source is shined on the phosphorescent strip that contains photons whose energy is less than the critical energy for the phosphorescent strip, no glowing will occur, no matter how bright the light source.

The cutoff wavelength for exciting the phosphorescent strip is about 480 nm. Photons (light energy) with a higher wavelength (less energy) will not cause the strip to glow, while photons with shorter wavelengths (more energy) will cause the phosphorescent glow. The cutoff wavelength of 480 nm is right on the border between blue and green light. Therefore, blue or violet photons which are transmitted through the filter will contain enough energy to excite the electrons in the phosphorescent material and cause it to glow. The green, yellow, orange and red filters, in contrast, absorb the blue and violet photons (their complementary colors) and do not allow them to be transmitted. Therefore, the light transmitted through these filters does not contain enough energy to excite the phosphorescent strip and no glow is observed.

The Visible Spectrum

The following table lists the wavelengths associated with each of the colors in the visible spectrum and their complements.

Wavelength Region, nm	Color	Complementary Color
400–425	Violet	Yellow-green
425–480	Blue	Orange
480–500	Blue-green	Red
500–560	Green	Red-Violet
560–580	Yellow-green	Violet
580–585	Yellow	Violet
585–650	Orange	Blue
650–700	Red	Blue-green

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation

Content Standards: Grades 5–8
Content Standard B: Physical Science, properties and changes of properties in matter, transfer of energy.

Content Standards: Grades 9–12
Content Standard B: Physical Science, structure of atoms, structure and properties of matter, interactions of energy and matter

Materials for the *Light Energy Demonstration* are available as a kit, called *Energy in Photons Kit*, from Flinn Scientific, Inc.

Catalog No.	Description
AP4576	Energy in Photons Kit
P0272	Phosphorescent Flash Paint
AP4794	Phosphorescent Vinyl Sheet, 12 × 12

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.